TECHNICAL BULLETIN NO. 52 JANUARY 1963

Irrigated Sugar Beet Production on Maui

O. R. YOUNGE

and

D. H. BUTCHART

HAWAII AGRICULTURAL EXPERIMENT STATION, UNIVERSITY OF HAWAII

CONTENTS

Introduction 3

Literature Review 4

Materials and Methods 7

Results and Discussion 11

Observed beet production 11

Estimated potential beet production 16

Comparison of beet and cane production of sugar 17

Conclusions 17

Summary 18

References 19

Appendix 21

Table 1. Sugar production, beet and cane, raw value (96° polarity), by principal areas supplying continental United States markets with sugar. 21

Table 2. Site data and rainfall at sugar beet test sites, H. C. & S. Co. plantation, Maui 22

Table 3. Significance of various experimental factors in the production of two crops of sugar beets, H. C. & S. Co. plantation, Maui 23

Table 4. Plant stand, percent of full stand of sugar beets at harvest, H. C. & S. Co. plantation, Maui, 1959–60. 24

Table 5. Yields of clean beets, tons per acre, H. C. & S. Co. plantation, Maui. 25

Table 6. Yield of fresh, trimmed sugar beet tops, first crop, tons per acre, H. C. & S. Co. plantation, Maui. 26

Table 7. Average weight of clean and trimmed sugar beets, pounds, H. C. & S. Co. plantation, Maui. 26

Table 8. Average sugar beet juice polarization percent, H. C. & S. Co. plantation, Maui. 27

Table 9. Average sugar beet juice purity percent, H. C. & S. Co. plantation, Maui. 28

Table 10. Average yield of sugar beet sugar, tons of sugar per acre per month. 29

Table 11. Potential yield of sugar, tons of sugar per acre per month, for sugar beets adjusted to full stand, H. C. & S. Co. plantation, Maui. 30

Table 12. Comparison of estimated sugar production from sugar beet test fields with actual sugar yields of the same fields with sugar cane, H. C. & S. Co. plantation, Maui. 31

CONTENTS, Continued

Figures

Figure 1. Sugar beets about 6 weeks old being weeded for the second time. Pulehu, Maui. 8

Figure 2. Second crop of sugar beet variety U. S. 401, at 6.8 months of age, ready for harvest. Kihei Field. 9

Figure 3. Sugar beet variety U. S. 401, at 6.8 months of age, ready for harvest. Kihei Field. 10

Figure 4. Sugar beets being fed onto the cane blanket at the sugar mill to observe their response to milling operations. Puunene, Maui. 13

Figure 5. Seasonal distribution of 5-year mean daily solar energy at test sites, H. C. & S. Co. plantation, Maui. 32

Figure 6. Seasonal distribution of 6-year mean daily maximum and minimum temperatures at test sites. H. C. & S. Co. plantation, Maui 33

Figure 7. Relationship of leaf weight to beet weight for experimental sugar beets, H. C. & S. Co. plantation, Maui. 34

Figure 8. Relationship of polarization percent to purity percent for experimental sugar beets, H. C. & S. Co. plantation, Maui. 35

Figure 9. Relationship of monthly yields of test sugar beets to yields of sugar, H. C. & S. Co. plantation, Maui. 36

THE AUTHORS

DR. O. R. YOUNGE is Agronomist at the Hawaii Agricultural Experiment Station; Chairman, Department of Agronomy and Soil Science, College of Tropical Agriculture; and Professor of Agronomy and Soil Science, University of Hawaii.

D. H. BUTCHART was Horticulturist at the Hawaiian Commercial and Sugar Co., Ltd., 1956–61. He is presently Agricultural Planner, Department of Agriculture, State of Hawaii.

Irrigated Sugar Beet Production on Maui

O. R. YOUNGE and D. H. BUTCHART

INTRODUCTION

Growing of sugar beets (*Beta vulgaris saccharum*) in Hawaii for the production of sugar is proposed periodically as an alternative to production of sugar cane (*Saccharum officinarum*). Both crops have been moving out of their traditional areas of production because of progressive improvements in varietal adaptation and yield, induced by hybridization of superior lines with various wild varieties and closely related species, and the two crops may eventually supplement each other or compete for the same land in some regions.

Currently also, there is a clamor by domestic and foreign producers alike for larger quotas of the United States sugar market, which has been strictly controlled since the depression days of the 1930's through a system of production quotas for domestic producers tied in with import quotas for foreign producers.

Cancellation in 1960 of the Cuban quota of 3.3 million tons of sugar has intensified the struggle for shares of the U. S. market. The reason for the intensity of this struggle is that the U. S. market pays a premium of about \$40 per ton above the open world market price of \$70 to \$90 per ton of sugar. It may be argued that in time the American consumers may decide to terminate what amounts to a bonus of \$40 per ton of sugar to domestic and foreign producers alike, and by increasing or eliminating the quotas cause U. S. market prices to fall to the lower world market levels. Any drastic price change would likely result in severe and drastic changes in the domestic sugar industry.

In table 1 are shown the data on sugar production in the principal beet and cane areas supplying the U. S. sugar market for the period 1950 to 1959. It will be noted on the basis of 96° sugar yield per acre that sugar beets grossed \$252 per acre annually as an average for the 1950–59 period. Cane sugar for the same period grossed \$210 for continental U. S., \$324 for Puerto Rico, and \$525 for Hawaii. For the foreign areas, gross acre returns were about \$80 to \$100 less than corresponding U. S. production when priced at the open world market, as shown by the Cuba value of \$158 per acre. It is apparent from the acre values presented that sugar beets are fully competitive with sugar cane. Where both crops are equally adaptable the choice will likely depend on the relative costs of production. Foreign production traditionally has been conducted on cheaper land and at lower labor costs than U. S. production. Consequently, foreign production receives a substantial bonus on the part of the sugar crop sold under quota control on the U. S. market. For Cuba, the premium over the world market price of about $40 per ton of sugar under the U. S. quota, amounts to an extra bonus of about $70 per acre in cane.

The U. S. program payments which range around $2.35 per ton of sugar for beets and $1.15 for cane are paid out of levies on the sugar industry and thus do not represent a net gain to the industry.

The field experiments on sugar beet production of two consecutive crops in 1959–60 at the Hawaiian Commercial and Sugar Co. plantation on Maui, here reported, were undertaken to provide information on the culture and yield of beets under local field conditions, and to evaluate the results for beets in terms of the performance of sugar cane produced under comparable conditions (*17*).

LITERATURE REVIEW

All growing plants make sugar in some form. Attempts have been made in the past to produce sugar on a commercial scale from sources such as apples, pears, figs, mulberries, plums, quinces, watermelons, ti roots, walnuts, chestnuts, sugar cane, and sugar beets. Only the cane and the beet produce sugar in sufficient quantities to justify commercial production.

The sugar beet enterprise had its inception with the discovery in 1747 by A. Marggraf, a German chemist, that the sucrose stored in the beet root could be readily crystallized and that it was identical to that in sugar cane (*7*). Achard, a student of Marggraf, built the first sugar beet factory in Silesia, Germany, in 1801, but it failed primarily because the beet sucrose content of less than 4 percent was too low (*7*).

Production of sugar beets spread into France, where it came to the attention of Napoleon, who in his enthusiasm for the sugar potentialities, established research and teaching facilities on beets and caused some 40,000 hectares of beets to be planted. In the meantime, Vilmorin had developed beets with a sugar content up to 17 percent (*7*).

Commercial sugar beet production began in the United States in 1838, in California. By 1959, sugar beets in the U. S. were being grown on 905,400 acres in 22 Western and North Central states with California, Colorado, Idaho, Michigan, Minnesota, Nebraska, and Montana producing 78 percent of the sugar (*19*). Texas with 1,770 acres and New Mexico with 800 acres of beets were the smallest producers in 1959 (*19*).

The modern sugar beet is the standard sugar-producing crop in the temperate climatic zones and is, in fact, the only economically feasible sugar crop for cool climates or where freezing soil temperatures would prevent the survival of sugar cane, the prevailing sugar crop in tropical and subtropical regions. Of the current annual world production of about 63 million tons of sugar, about two-thirds comes from cane produced in tropical areas, and the remainder from beets grown in temperate areas.

On the Mainland, sugar beets are grown almost entirely in rotation with legumes, small grains, and row crops. Single cropping or continuous culture of beets soon results in depressed yields due to rapid increases in seedling diseases.

The sugar beet is a true biennial with vegetative growth and great taproot development in the first season and seed production in the second growing season. The cone-shaped taproots, about 18 inches long and average weight in excess of 2 pounds, are harvested and processed for sugar, while the top growth may be ensiled and utilized for animal forage (*2, 7, 10, 15*). The sugar content ranges from 12 to 22 percent of the fresh weight of the trimmed root. Regional yields average 6 to 15 tons of beets per acre, but individual fields will frequently go as much as 25 to 30 tons per acre under favorable conditions. Sugar beets are sensitive to injury from diseases and insects, and are especially vulnerable during the seedling stage. For sugar production, each beet crop is grown, on relatively stone-free, deep, well-prepared soil, from seed planted in rows about 20 inches apart, and later thinned to one plant for every foot in the row. The use of monogerm and segmented seed, mechanical blocking and thinning, and herbicides, is reducing much of the hand labor which is incident to the thinning and weeding of crops grown from polygerm seed. The main climatic requirements for sugar beet culture are mean temperatures near 70° F., moderate amounts of water during the main growing period, and dry weather or some other factor which will effectively arrest vegetative growth and promote sugar storage in the root, towards the end of the 5- to 7-month growing season. These environmental requirements fit sugar beets to the very extensive temperate zone corn belt and soybean regions, and to dryland areas adaptable to irrigation. Even tropical desert areas when planted in the winter season will produce satisfactory yields of sugar by early summer if the water is so carefully limited as to divert the products of high photosynthetic activities away from vegetative growth into storage of sugars. The sugar beet plant is fragile when a seedling and requires careful management during the early half of its growing period. Neglect in the early stages or slightly unfavorable growing conditions can result in poor stands and reduced yields.

Sugar cane is an ancient agronomic crop whose origin is lost in the mists of history. The crop was brought to the western world from India by navigators from Portugal and Spain in the 15th century. Sugar cane is one of the first crops in the world that was grown extensively for industry and trade. Modern commercial sugar canes are directly related to several wild cane species of little agronomic value which still can be found in tropical areas of the Pacific. Modern canes have been greatly modified and altered from their wild ancestors through selective breeding over several centuries of time, with major improvements having been attained since about 1850.

The sugar cane crop is primarily adapted to extensive areas in tropical and subtropical climates. It has a high water requirement and a variable growing period regimented by climate. To grow and mature a crop for harvest of sugar takes, usually, 9 months in Louisiana, 12 to 14 months in Florida, and 22 to 24 months in Hawaii. The temperature needs to be high enough to permit rapid growth of the cane for 70 to 80 percent of the growing period, followed by a dry or cool period which nearly terminates vegetative growth and induces increased sugar storage in the enlarged stem, which is cut and processed for its sugar. Sugar cane is a robust, fibrous-rooted, thick-stalked, many-stemmed, perennial grass that may exceed 15 feet in height when mature. It is propagated commercially from stem cuttings which are laid in furrows 4 to 5 feet apart on well-prepared land and covered with soil. In tropical or frost-free areas, 2 to 5 cane crops or ratoons are usually harvested over a period of 4 to 10 years or more before tillage and replanting becomes necessary because of stand depletion and reduced yields. Where winter frost kills the cane tops, as in Louisiana and Florida, 3 to 5 successive annual crops are harvested before replanting is necessary. In such areas, cuttings from about 12 percent of the crop are stored over winter and planted as the plant crop in the following spring. Cane is relatively resistant to disease and insect injury, and weed control is required only during the first 2 to 4 months following planting and harvesting, or until the slowly growing crop shades the ground. The sugar cane plant, in common with most perennial grasses, is rugged and, having high survivability, is able to withstand neglect and abuse and is therefore well suited to routine, large-scale, mechanized, single crop culture over a wide range of growing conditions and management.

Sugar beet culture has been tried on a small scale several times in the past in Hawaii; the first reference in the literature is to field trials at Maui Agricultural Co., Paia, Maui, in 1910, and on Lanai in 1910–11 (*9*). Little apparent success attended these early trials. Likewise, no apparent success was obtained with sugar beet accessions tested at the Hawaii Agricultural Experiment Station in 1917–18.

In 1948, the Hawaiian Sugar Planters' Association conducted field trials at Makiki and Kailua on Oahu, using U. S. varieties Nos. 15, 22, and 33 (*20*). Seeds were germinated in sterile greenhouse soil and later transplanted to the field. The crops matured in 5 months from time of transplanting. The yield of harvested beets averaged 19 tons per acre, with a sugar content of 0.45 ton of sugar per acre per month. In these trials, the sugar content of the beets was near the bottom of the usual 12 to 22 percent sugar range.

Taiwan Sugar Experiment Station has reported on sugar beets as an inter-row crop with sugar cane, a common practice with certain truck crops, during the first 6-month period of their 12- to 18-month sugar cane cycle (*3, 4*). The experiments are of interest because of Taiwan's similarity in geographic latitude and climate to Hawaii. The results from several hundred widely distributed field trials in Taiwan, in which European and North American beet varieties were used, show that the most productive growing period is from October to March, during the adequate monsoon rains. Results for the 5-year period starting in 1955 showed that sugar beets grown in rotation with other crops prevailingly performed as follows:

> Growing period 5.5 to 6 months, beet yield 18 to 22 tons per acre; yield of tops 6.5 to 9 tons; sugar yield 2.4 to 2.9 tons per acre or 0.40 to 0.48 ton per acre per month.

When grown as an intercrop with cane, the sugar yield is about 10 percent lower than when grown in a crop rotation. Also, beet production with irrigation is substantially superior to dryland culture.

Wailuku Sugar Co., Maui, reported field testing of sugar beets, which was conducted in the first half of 1960 (*1*), using U. S. beet varieties. Yields of unirrigated beets over a 4.5-month growing period were 10.6 tons of beets and 1.90 tons of sugar per acre, producing 0.42 ton of sugar per acre per month. By comparison, the local irrigated sugar cane currently averages 88 tons of fresh cane and 10.16 tons of sugar per acre, producing 0.47 ton sugar per acre per month. In this comparison, the time required for field preparation prior to planting of the beets has been ignored but, properly, it should be included for a more precise evaluation.

MATERIALS AND METHODS

To determine the potentials of sugar beet culture under conditions comparable to sugar cane production in Hawaii, four field sites were selected to encompass some of the variability in soils and climate found within the extensive cane area of the Hawaiian Commercial and Sugar Co. plantation on Maui. The test fields, all on old, level cane land, have been producing irrigated cane for periods of 75 years or more. The field sites were Spreckelsville field 609, elevation 75 feet; Kihei field 817, elevation 200 feet; Paia field 204, elevation 525 feet; and Pulehu field 405, elevation 650 feet. The two mauka fields, Paia and Pulehu, tended to be unfavorably damp and cloudy during the wet season of the year in winter, while the lower sites were generally dry and clear at all seasons.

To establish the beet crop the land was thoroughly tilled, broadcast-treated with a complete fertilizer, disced in, and fumigated with 15 gallons Telone per acre to control nematodes. The land was contour-furrowed at 22-inch centers and nonsegmented sugar beet seed at 4 pounds per acre or its equivalent was mechanically drilled to a depth of about 0.5 inch on the top of the contour furrows for the first crop, and thereafter planted by hand. In the 4- to 6-leaf stage the stand was thinned to a plant distance of about 12 inches, and all crop cultivation and weeding was done by hand. After crop planting, the fields were furrow-irrigated to field capacity at 7-day intervals during the early two-thirds of the growing period wherever dry conditions prevailed, and later, irrigation was reduced or discontinued in order to promote maximum storage of sugar during ripening of the beets.

At each of the four sites, four U. S. sugar beet varieties, representative of the wide range of superior commercial varieties currently in use on the

Mainland, were planted in randomized blocks with eight replications. The plot size was 20 × 20 feet or roughly 0.01 acre, providing 220 feet of row and about 220 beets per plot.

Prior to harvesting the beets, the blanks or misses were measured in each plot, the aggregate length of each empty row space minus one foot being used in adjusting the observed yield to a full yield equivalent. Harvesting was begun when the beets in a test area were considered as mature, on the basis of cessation of vegetative growth and maturation of the leaves. All the rows of each plot were harvested for yield data. The soil along the row was loosened with a spading fork, the beets lifted out by hand, and adhering loose soil removed. The beets were then topped and trimmed with a cane knife. Beets and fresh tops were weighed separately. For each plot a weighed sample of 10 beets taken at random was collected for laboratory analysis. In the laboratory, the beet samples were washed to obtain clean weights, and further subsamples were taken for analysis of sugar polarization and purity. In all analyses current standard procedures were used.

FIGURE 1. Sugar beets about 6 weeks old being weeded for the second time. Severe weed competition lowers beet yield. Selective herbicides harmless to beets are required for economic weed control. Hand-weeding of beets in any form is probably too costly under Hawaii conditions. Pulehu Field.

The sugar beet varieties used in the tests were US 56/2, US 75, US 201, and US 401. These varieties as a group represent adaptability over a wide range of conditions in the sugar beet areas of the Mainland and could be expected, therefore, to fit a wide range of conditions in Hawaii.

Meteorological data were available for each test site from local or adjacent stations which have been in operation for several years as a part of a plantation-wide network. Appropriate climatological data were correlated with field performance of the sugar beets where definite relationships appeared to exist.

The soils at the test sites are Low Humic Latosols developed on weathered volcanic rock and ash materials under variable droughty conditions (5). The Molokai soils occur below 1,500 feet elevation under an annual rainfall of less than 30 inches and they are prevalent in vegetation zone A. They consist mostly of deep, highly weathered material several feet thick over bedrock. The soil reaction is pH 6 to 7. These soils are well

FIGURE 2. Second crop of sugar beet variety US 401, at 6.8 months of age, ready for harvest. The average weight of trimmed beets was slightly over 2 pounds. US 401 outyielded three other varieties, with yields at four locations ranging from 17 to 31 tons per acre per crop for two crops per year. Kihei Field.

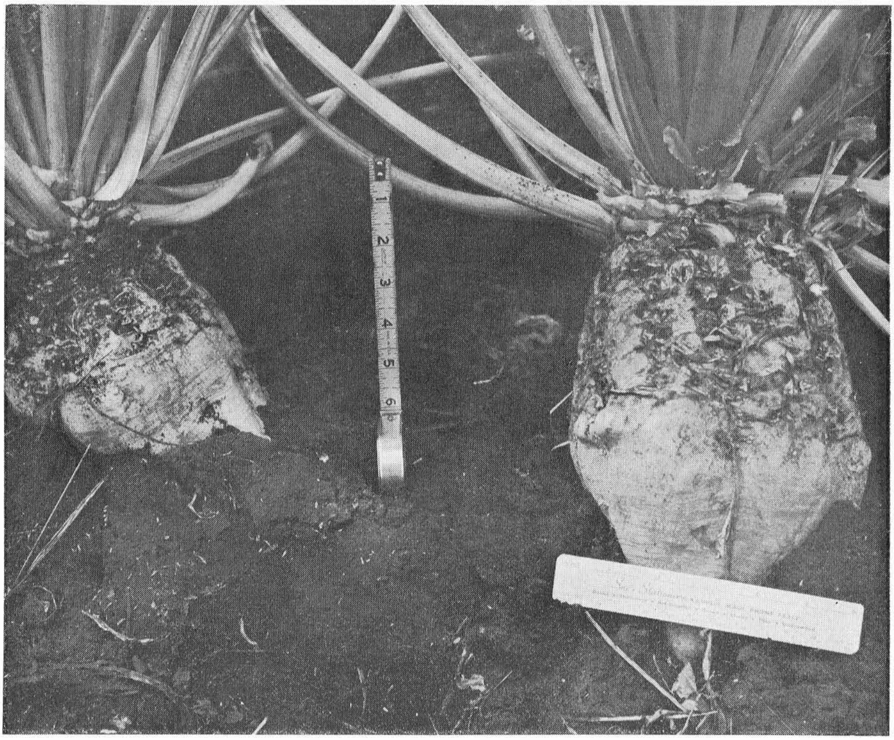

FIGURE 3. Sugar beet variety US 401 at 6.8 months of age, ready for harvest. The largest beet shown in this photo weighed 19 pounds after trimming. Kihei Field.

supplied with bases, especially potassium, are low in nitrogen, have a high capacity to fix phosphorus, and are especially suited for irrigation culture.

The Lahaina soils occur chiefly at elevations below 1,500 feet, mainly in vegetation zone B, and prevailingly under a rainfall of 20 to 40 inches per year. These soils are brown to reddish brown and are otherwise similar to the Molokai soils, except as they are modified by a more generous water regime.

The Kohala soils, as represented by the Paia site, occur at elevations from 500 to 1,500 feet, under a rainfall of 40 to 60 inches, and lie entirely in vegetation zone C. The Hamakuapoko series comprising the test site is characterized by a tight layer below 2 feet, which might impede internal drainage. Due to the high rainfall, the soils are moderately leached with a reaction of pH 5 to 6.5. The soil is low in nitrogen, is possibly low in potassium, fixes phosphorus readily, and should show response to lime for certain crops. For sugar cane, irrigation is required and yields are lower than for drier and sunnier areas. Most of the soils of the series are in pineapple without irrigation.

RESULTS AND DISCUSSION

Two crops of sugar beets were grown in succession at four diverse test sites on old cane land on the Hawaiian Commercial and Sugar Co. plantation on Maui, as described under Materials and Methods. The weather during the two crop periods was normal as shown by the meteorological data, table 2. The performance data on the test sugar beets were subjected to statistical analysis of variance, with the results shown in table 3. This analysis shows that in beet yield and sugar yield the factors of site, variety, variety × site, and site × crop were significant. The quality of the product as represented by polarity percent and purity percent was significantly affected only by site, variety, and site × crop. The crop, variety × crop, and variety × site × crop variants were nonsignificant throughout, except that the crop was significant in beet yield when plant stand was adjusted to full stand.

Inasmuch as the performance of the two crops differed, the second crop being considerably below acceptable standard, the results will be presented first as they were actually observed, and second as they appear after adjustment to full or 100 percent plant stands. The adjusted performance is considered to represent a fair estimate of the potential yield in the absence of damping-off diseases and mechanical malfunctions in planting and crop growing.

Observed Beet Production

The first beet crop was grown in the 4.8-month period of March to July 1959, followed by the second crop period of nearly 6.5 months ending in March 1960.

The first crops were grown without difficulty. However, the second crop attempted at the Paia site, planted in the humid August–September period, failed to produce more than a 5 percent plant stand in three seedings. Young seedling beets perished through damping-off diseases (7), and the test was abandoned.

Table 4 records the plant stand at harvest time for the various sites and beet varieties. The small loss of stand in the first crop resulted from nondelivery of seed due to hang-up of the seed in the planting machine.

The second crop stand loss is attributed mostly to seedling diseases, which resulted in about 8 percent loss at dry Kihei, 44 percent loss at more humid Spreckelsville, 27 percent loss at dry Pulehu, and complete loss of stand and no yield at Paia. It will be noted that the soils were fumigated with Telone[1] prior to the seeding of each crop. The stand or population counts showed conclusively that no success in sugar beet production is possible under most Hawaii conditions until seedling diseases can be effectively controlled.

---

[1] Telone is a trade name (Dow) for 1,3-dichloropropenes.

An attempt was made to correlate the yield at the various test sites with the solar energy in terms of total monthly gram-calories/cm^2 recorded near the test sites. Data for the 5-year period, 1954 to 1958, were calculated to give the mean gram-calories per day for each month in the year as shown in figure 5. It will be noted that Paia with the poorest yields of beets shows highest solar energy values in summer and slightly the lowest in winter. The various solar energy curves follow closely the seasonal flow in daylength hours and appear to be nearly similar. The first crop, produced from March through July, received considerably more solar energy than the second crop grown from August through February. As shown by the data on yield of sugar per acre per month (table 11), the sugar yield is potentially about the same for the two seasons. It is concluded, therefore, that the available solar energy is adequate at all seasons for sugar beet production.

An attempt was made to correlate the site yields with the daily maximum and minimum temperatures as shown in figure 6. It will be observed that the 6-year mean seasonal values are relatively uniform with maxima at about 90° F. and minima at 60° F.; and that the temperatures show little correlation with daylength, and, by extension, with solar energy distribution. Paia with the poorest yield shows a narrow, 12-degree range between mean maxima and minima values. At the other extreme, Kihei, with the highest yields, shows a range of about 26 degrees and is prevailingly both the warmest and the coldest site. It was noted earlier that cool nights promoted the storage of sugar in the maturing sugar beets, and this together with controlled limitation of soil water probably accounts for the superiority of the dry hot areas for sugar beet production in this study. Paia, it will be noted, had considerable rain throughout the first crop period and, therefore, vegetative growth continued although the yields of both beets and sugar were very low.

Table 5 shows the actual or observed yield of fresh, clean sugar beets in tons per acre by beet variety and by site. In some instances yields for the second beet crop are higher than for the first crop. This is a result of the difference in growing period, which was about 4.8 months for the first crop and 6.5 months, for the second. When yields are calculated to a uniform base of yield per acre-month, the yields are lower for the second crop.

The beet yields differ significantly at the different sites for each of the two crops. The Kihei site is the most productive followed by Spreckelsville, Pulehu, and Paia with ratios of 100, 94, 66, and 29, respectively, in the first crop. In the second crop, differences in stand favor Kihei and Pulehu, but the actual yield-rank of the sites remains the same as in the first crop. The top-yielding Kihei site recorded mean yields for clean beets of 23.1 and 26.8 TPA (tons per acre) for the first and second crops, respectively. The mean total for the full year and two crops is 49.9 TPA, with a range of 42.5 to 55.5 TPA.

On an average, the second-ranking Spreckelsville site produced 21.7 and 17.8 TPA of beets for the first and second crops, for a total of 39.5 TPA or 79 percent of the Kihei yield.

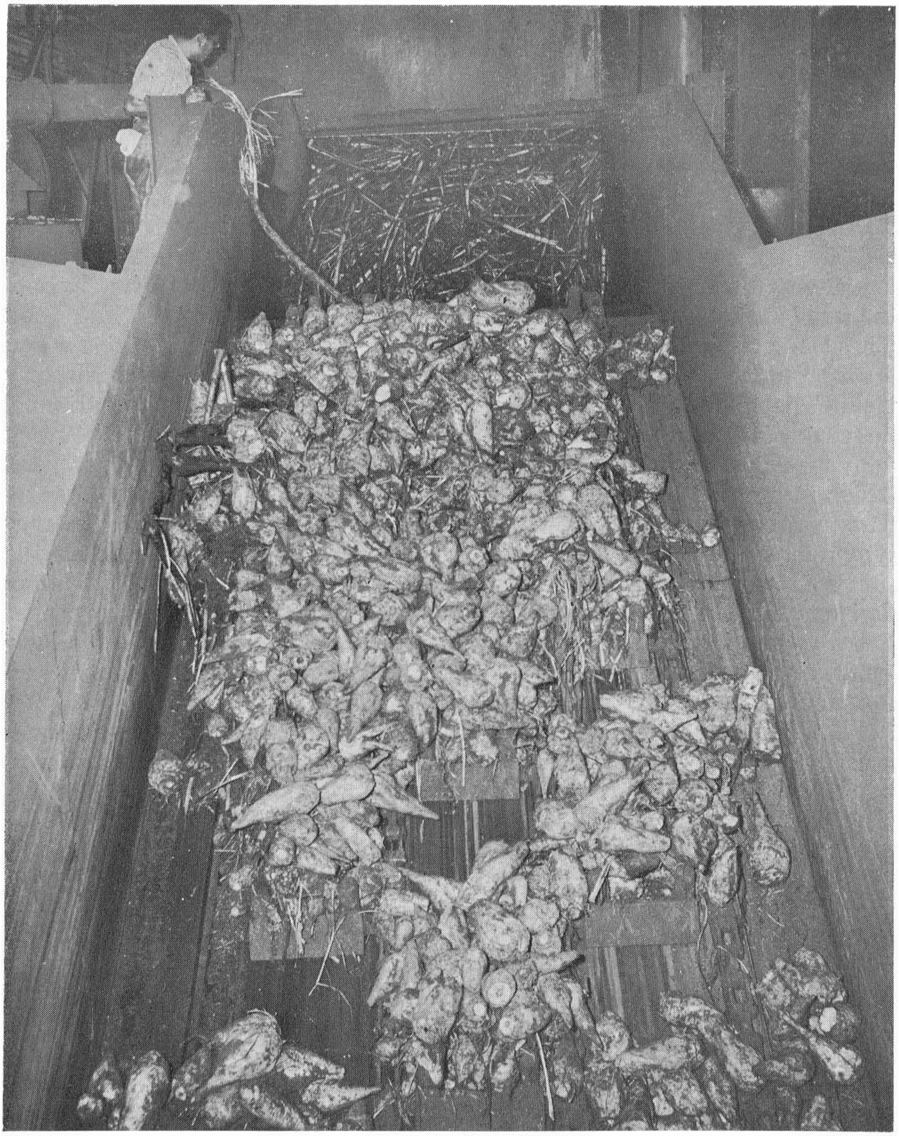

FIGURE 4. Sugar beets being fed onto the cane blanket at the sugar mill to observe their response to milling operations. Hawaiian Commercial and Sugar Co., Ltd., Puunene, Maui.

The third-ranking Pulehu site produced first and second crops of 15.2 and 16.3 TPA, for an annual total of 31.5 TPA of beets or 63 percent of the Kihei yield.

The Paia site on Kohala soils under humid weather conditions produced an average of only 6.7 TPA of beets in the first crop despite the fact that the stand was 90.4 percent of a full count. No second crop was produced inasmuch as three successive seedings were damped-off and the stand fell below 5 percent. Sugar beet production on Kohala soils as represented by the Paia site, at this stage, appears to be entirely infeasible on two counts: first, the loss of stand resulting from disease as exemplified by the test data; second, the small size of the beets and the poor total yield of beets even with a good plant stand. The first crop with small beets of 0.7 pound average weight and a total yield of beets at 6.7 TPA is at best only one-third of a satisfactory yield. The poor yield at Paia suggests the presence of some nutritional deficiency. It should be noted that all sites were fertilized before planting with materials at rates to give NPK of about 60-40-60 pounds per acre, which is very likely far too little on land long cropped to sugar cane. Likewise, no boron or other minor elements were added. Slight deficiency symptoms of boron were noted in most plots at all sites. At the Spreckelsville site the second beet crop showed more severe leaf symptoms of boron deficiency. The boron deficiency observed as well as other nutrient shortages probably reduced yields but no estimate of the loss is available. In any event, boron deficiency does not appear to account for the poor beet performance at Paia.

With respect to sugar beet variety performance at the four test sites, it is apparent that variety had little or no effect on stand counts in two successive crops. This suggests that there was no differential resistance to damping-off diseases in the variety seedlings tested. In yield ability the actual beet production shows US 401 and US 75 to be equal, with beet yields of 43 TPA for two crops per year. US 56/2 is a close contender with 40 TPA. US 201, with 82 percent yield of the leaders, yielded 36 TPA.

It is noteworthy that none of the varieties bolted or showed any tendency to bolt or flower in any of the field trials. This is noteworthy, since under certain mainland conditions, US 401 is particularly noted for this undesirable characteristic which results in lowered yields.

In table 6 are shown the yields for the tops trimmed from the beets of the first crop only. The data for the Kihei, Spreckelsville, and Pulehu sites show top yields of 14.4 to 7.1 TPA, which are about 50 to 60 percent the weight of the corresponding clean beets. However, at Paia, yields of tops are only 4.5 to 6.4 TPA and generally exceed the corresponding yield of beets. If it may be assumed that large leaf size, as measured by high leaf yield, is a requirement for heavy beet production, then it is evident that some unknown factor or factors prevented large leaf development in the beets at Paia and that this in turn limited mature root development. The average weight of clean beets by variety and site is shown in table 7. Weight of first crop beets at Pulehu and Paia fall well below the usual 2-pound standard beet weight. As shown by figure 7, there is good correlation between first crop leaf weight and beet weight in the range of 0.5 to 2.5 pounds per beet (*6*), the curve conforming to the general exponential equation $y = M(1-R^x)$. The shape of the correlation curve shown in figure 7 indicates that on the average for the conditions found in these tests, increasing the size or weight of leaves per beet beyond 1.5 pounds would result in no further increase in unit beet weight beyond 2.5 pounds. This suggests that increasing by whatever means the leafiness of the beets is not a promising way to increase the yield of beets. However, changes in the genetic character through breeding could probably alter the leaf–root ratio of new beet varieties and so upset the above conclusion. Also, closer spacing of plants by reducing row distance and within-row spacing of plants may be expected to increase total leaf area and yield but at the same time reduce the size of the individual beets. In the current field trial the beet stand spacing of 22 × 12 inches is one commonly utilized by mainland producers and is not necessarily the most productive spacing for local conditions.

The quality of the beets at the test sites is indicated by the beet juice polarization and juice purity values shown in tables 8 and 9. Differences in quality exist between the beets for site, variety, and site × crop interaction. The data show that Pulehu beets are superior in both polarity percent and purity percent for the two crops, followed by Kihei and Spreckelsville beets (fig. 8). On the basis of the first crop only, the Paia beets test second to Pulehu beets in sugar turnout.

In the second crop, both polarity and juice purity are inferior at Spreckelsville and this is reflected in lower sugar yield for this site.

The varietal differences in polarity and juice purity values while significant are nevertheless relatively small and unimportant.

The uniformly low polarity and juice purity values found in these field experiments indicate that Hawaii sugar beets rank near the bottom in sugar content, which for commercial beets ranges between 12 and 22 percent sugar.

The sugar content of the experimental beets is comparable to the values previously reported for beets grown at Makiki and Kailua, Oahu (*20*).

Sugar crops require growing periods varying in length or number of days to produce yields. Therefore, in any critical evaluation of sugar crop performance, the actual yields of sugar must be compared on the basis of a uniform time unit. The Hawaii sugar industry bases yield performance on TSAM (tons of sugar per acre per month). Table 10 shows the beet sugar yields calculated on this basis. No account is made for the time between crops, which for sugar beets would include time for land tilling and fitting prior to planting. If this period is also assessed against the beet crop, the TSAM values obviously are going to be reduced. The test results showed that the actual beet yields varied significantly between crops, sites, and varieties, in conformity with variations in growing period, beet yields, and sugar content as reported above (fig. 9).

For the first crop at all sites and varieties, the range in sugar yield is 0.127 to 0.549 TSAM. For the second crop, the range is 0.000 at Paia to

0.489 for US 75 at Kihei. For the two crops combined, Kihei leads with an average yield of 0.481 TSAM; Spreckelsville and Pulehu are tied with yields of 0.372 TSAM. The Paia site produced only a first crop, which averaged 0.158 TSAM. The second crop failed due to disease in the seedling beets.

The varieties differ in sugar-yielding capacity in conformity with differences in stand, beet yield, and quality. The varieties US 401 and US 75 lead with an average yield for three sites and two crops with 0.433 and 0.420 TSAM, respectively. US 56/2 averaged 0.403 TSAM or 93 percent of the leader, and US 201 trailed with 0.374 TSAM or 86 percent of the leading variety production. These yields, while fairly satisfactory, are not equal to the yields from sugar cane, as will be shown later.

Estimated Potential Beet Production

The purpose of the experimental production of sugar beets in the sugar cane area of Maui was to establish the potentials for this crop under good management for comparison with actual sugar cane production. As shown in this report, the actual beet performance fell short on three major counts: (1) The beets at some test sites failed to produce full stands because of disease in the seedling stage, the extreme case being the complete failure at Paia in the second crop. This severely cut down the yields. (2) The beets were somewhat undersize, as was the case at Pulehu and Paia. This also reduced yields. This problem appears to be nutritional in character and consequently can be corrected by fertilization. (3) The quality of the beets or the sugar content is below par, being only 12 to 15 percent sugar, which is at the lower end of the range of commercial beets with sugar values of 12 to 22 percent. The low quality of the beets drastically limits the sugar yield. This problem is probably partly one of controlling the ripening process to induce greater storage of sugars, and partly, also, a matter of selective plant breeding to develop beet varieties with higher sugar content.

It appears a valid assumption that the yields would vary directly with plant stand and, therefore, that adjustment of the yield to full stand of beets would give a fair estimate of the potential production if seedling diseases were minimized. No corrections or adjustments seem valid for undersized beets or for low sugar content.

The potential yields of sugar when beet yields are adjusted to 100 percent stand are shown in table 11. It will be noted that in this tabulation only the Paia site shows poor performance. The range in production for the four varieties for two crops is from 0.360 to 0.542 TSAM. The Kihei site averaged 0.513, Spreckelsville, 0.446, and Pulehu, 0.426 TSAM. The over-all average sugar beet yield is 0.462 TSAM. This appears to be satisfactory production.

With respect to beet varieties, the Great Lakes variety US 401 led production with 0.503 TSAM, and exceeded varieties US 75 by 6 percent, US 56/2 by 9 percent, and US 201 by 18 percent.

Comparison of Beet and Cane Production of Sugar

One of the major objectives of this series of field experiments was to compare sugar yields from beets and cane in the local sugar cane environment. For this purpose, use is made of actual sugar production for the cane grown at the four test sites covering the period from 1949 to 1957, comprising four harvests at all sites except Pulehu, which included five harvests. The comparison of experimental yield of sugar from beets with that of commercial sugar yields from cane will favor the beet production to the extent that the beet production reflects no processing losses due to harvesting and milling of the beets; also, if no lost production during land preparation for planting is included.

Comparison of the actual sugar production from beets per planted acre including the second crop that failed at Paia, with the historical yields of cane sugar for the four sites (table 12) shows that Kihei yields of sugar are about the same, 0.481 TSAM from beets and 0.467 TSAM from cane. For the other sites the cane outyielded the beets by 22 percent at Spreckelsville, by 30 percent at Pulehu, and by 84 percent at Paia. The inferiority of the beets is primarily a reflection of the stand loss resulting from seedling diseases.

The potential sugar beet production, with adjustments to full stands of beets, shows that Kihei and Spreckelsville beet sugar production is nearly equal to that from cane. For Pulehu, the cane is superior to beets by 20 percent. At Paia the beet production is obviously greatly inferior to cane production.

CONCLUSIONS

It is evident from the various yield data that sugar beet yields, actual and potential, are not superior to sugar cane yields in cane-producing areas of Maui. Over a short period, such as required for the production of two crops, the sugar beets, under favorable conditions, appear to be equal to sugar cane in yields of sugar. The irrigated, dry areas produce the highest yields of beets. The moist areas, such as Paia, are unsuitable for beets unless the disease and fertility disabilities are corrected.

In areas favorable for beets, it appears that beets could well serve as an interrow crop in sugar cane during the first 6-month growing period, while the stand of cane is open and using only a small portion of the growing medium. For this 6-month period, there is a potential yield of 2 to 3 tons of sugar. Likewise, beets could serve as an intercycle crop with cane. Also, beets can be used as a catch crop on otherwise idle lands when occasional periods of ample rainfall make excess irrigation waters, which otherwise would go unused, available for periods up to 5 to 6 months. Sugar producers could well exploit these potentials and thus increase their income.

Under continuous culture, sugar cane in Hawaii will always have a decided advantage in that it is a perennial crop which ratoons freely without much field preparation for each crop. Sugar beets, however, require full seedbed tillage for each crop, which increases risk of soil erosion, adds to costs, and delays production. Sugar beets, also, are susceptible to seedling diseases and require continuous weed control. The ultimate use of sugar beets as a supplemental or alternate crop to current Hawaii field crops will obviously depend on the economic situations involved.

The yield performance shows clearly that under favorable conditions, sugar beet production could be profitable as a supplementary crop in Hawaii.

SUMMARY

Results are presented for sugar beets grown at four sites on the Hawaiian Commercial and Sugar Co. plantation on Maui, the heartland of sugar cane production in Hawaii.

Two beet crops were grown consecutively on the same land. The first crop required about 4.8 months, and the second crop, 6.4 months. Both crops were irrigated. Low rainfall areas with highest day temperatures and lowest night temperatures, as represented by Kihei, produced highest yields. Moderate rainfall and less difference between day and night temperatures, as represented by the Paia site, resulted in lower beet yields.

Seedling diseases severely reduced plant stands in the second crop, and resulted in complete loss of stand at the moist Paia site.

The quality of the beets based on the sugar content was below commercial standards. The quality ranged from 12 to 15 percent sugar and lies at the lower end of the usual range of 12 to 22 percent sugar in beets. The low quality is attributed to unfavorable ripening conditions with too high temperatures (daily range 90° to 60° F.) and probably to excess soil moisture. Beet varieties US 401 and US 75 averaged 0.433 and 0.420 TSAM (tons of sugar per acre-month), respectively. US 56/2 produced 0.403 and US 201 yielded 0.374 TSAM for two crops at three sites, with Paia excluded.

Yields of clean beets for two crops were 49.9 tons per acre at Kihei, 39.5 at Spreckelsville, and 31.5 at Pulehu. The Paia site yielded 6.7 tons of beets per acre for the first crop only. Loss of plant stand resulting from seedling diseases seriously lowered beet yields at three sites.

The estimated total sugar yields for two crops in 1 year were 0.481 TSAM for Kihei, and 0.372 for both Spreckelsville and Pulehu. For Paia with only one crop, the yield was 0.158 TSAM. These sugar yields when adjusted for stand loss resulting from disease are as follows:

Kihei	0.513
Spreckelsville	0.466
and Pulehu	0.426 TSAM for a mean of 0.462.

The beet yields may likewise be compared to the sugar cane yields from areas immediately adjacent to the beet test sites.

The sugar cane yields for the 1949 to 1957 period were as follows:

Kihei	0.467
Spreckelsville	0.476
Pulehu	0.531
and Paia	0.484 TSAM for a mean of 0.490.

The yield data show that beet and cane yields are about the same for Kihei; for the other sites the cane outyields the beets by 22 percent at Spreckelsville, by 30 percent at Pulehu, and by 84 percent at Paia.

If, in these comparisons, stand losses of beets resulting from disease are eliminated, then Kihei and Spreckelsville beet and cane yields are nearly equal. At Pulehu the cane is superior by 20 percent and at Paia, by about 64 percent.

From these field experiments on sugar beet production it may be tentatively concluded that beet production in Hawaii is practicable only if seedling diseases are controlled, weeds are economically controlled, the average size of the beets is brought up to about 2 pounds, and the sugar content is increased from the current 12 to 15 percent to at least 18 percent sugar. Under present conditions, it is evident that beets cannot compete with sugar cane. However, beets appear to have a high potential as an interrow crop with cane during the first 6 months of cane plant and ratoon crops, and also as a catch crop on idle land when there is a temporary surplus of irrigation water. Present indications are that sugar beets are unsuited to areas with annual rainfall in excess of 30 inches because of seedling diseases and low soil fertility.

Development or breeding of superior varieties of beets could obviously negate these conclusions.

REFERENCES

1. ANONYMOUS. 1960. BEET CROP YIELD LESS THAN CANE. Honolulu Advertiser, June 5, 1960. Hawaii Agr. & Food Trade 17(6): 4.

2. BARMINGTON, R. D., and S. W. MCBIRNEY. 1952. MECHANIZING THE PRODUCTION OF SUGAR BEETS. Colorado Agr. Exp. Sta. Bull. 420A. 40 pp.

3. C. W. 1957. TWO YEAR SUGAR-BEET CULTIVATION EXPERIMENTS IN TAIWAN. An abstract of Taiwan Sugar Experiment Rept. No. 6. In: Taiwan Sugar 4(12): 18–21.

4. CHEN, CHIH. 1961. SUGAR BEET CULTIVATION UNDER SUBTROPICAL CONDITIONS IN TAIWAN. Crops Symposium, 10th Pacif. Sci. Congr.

5. CLINE, M. G., *et al.* 1955. SOIL SURVEY OF THE TERRITORY OF HAWAII. U. S. Dept. Agr., Soil Survey Ser. 1939, No. 25. 644 pp.

6. IBACH, D. B. 1956. A GRAPHIC METHOD OF INTERPRETING RESPONSE TO FERTILIZER. U. S. Dept. Agr., Agr. Handbook 93. 27 pp.

7. MARTIN, J. H., and W. H. LEONARD. 1957. PRINCIPLES OF FIELD CROP PRODUCTION. 9th printing. Macmillan Co., New York. 1176 pp.

8. MARTIN, L. F. 1951. THE PRODUCTION AND USE OF SUGAR CANE. Crops in Peace and War. U. S. Dept. Agr., Yearbook of Agr. Pp. 293–299.

9. MAUI AGRICULTURAL CO. 1910–11. SUGARBEET TRIALS ON MAUI. Honolulu Advertiser, 1911. Honolulu Star-Bulletin, 1911. Maui News, 1910.

10. MERVINE, E. M., and R. D. BARMINGTON. 1943. MECHANICAL THINNING OF SUGARBEETS. Colorado Agr. Exp. Sta. Bull. 476. 18 pp.

11. PATERSON, D. D. 1939. STATISTICAL TECHNIQUE IN AGRICULTURAL RESEARCH. McGraw-Hill Co., New York and London. 263 pp.

12. RASKI, D. J., and B. LEAR. 1958. CONTROL OF SUGAR-BEET NEMATODE. Calif. Agr. 12(5): 8.

13. ROBERTS, R. C., *et al.* 1942. SOIL SURVEY OF PUERTO RICO. U. S. Dept. Agr., Soil Survey Ser. 1936, No. 8. 503 pp.

14. SAVITSKY, HELEN. 1960. COMING: NEMATODE-RESISTANT SUGARBEETS. U. S. Dept. Agr., Agr. Research 8(12): 3–4.

15. STOUT, M., S. W. MCBIRNEY, and C. A. FORT. 1951. DEVELOPMENTS IN HANDLING SUGAR BEETS. Crops in Peace and War. U. S. Dept. Agr., Yearbook of Agr. Pp. 300–307.

16. TALIAFERRO, W. J. 1959. RAINFALL OF THE HAWAIIAN ISLANDS. State of Hawaii, Hawaii Water Authority. 394 pp. (Mimeo.)

17. UNIVERSITY OF HAWAII. 1958. AGREEMENT ON COOPERATIVE PROJECT ON SUGARBEET PRODUCTION. Hawaiian Commercial and Sugar Co., Ltd., December, 1958.

18. UNITED STATES DEPARTMENT OF AGRICULTURE. 1936. YEARBOOK OF AGRICULTURE. U. S. Govt. Printing Office, Washington, D. C. Pp. 625–656.

19. UNITED STATES DEPARTMENT OF AGRICULTURE. 1961. AGRICULTURAL STATISTICS, 1960. U. S. Govt. Printing Office, Washington, D. C. 632 pp.

20. WILLIAMS, D. E. 1948. REPORT OF SUGARBEET OBSERVATION TESTS, MAKIKI AND KAILUA, OAHU. Hawaiian Sugar Planters' Assn., August, 1948. (Unpublished.)

APPENDIX

TABLE 1. Sugar production, beet and cane, raw value (96° polarity), by principal areas supplying continental United States markets with sugar, averages 1950–59, annual 1959[1]

FACTOR		UNIT	UNITED STATES						PHILIPPINES	CUBA[5]
			Beet Sugar	Cane Sugar				Total		
			Continental U.S.A.	Continental U.S.A.	Puerto Rico	Hawaii[2]	Virgin Islands			
Growing period		Months	5–6	9 Louisiana, 12 Florida	12–16	20–24			9–12	12–16
Acres grown	1950–59 av.	Acres (000)	868	305	405	220			525	3078
	1959	Acres (000)	955	319	386	223			555	3865
Acres harvested for sugar	1950–59 av.	Acres (000)	810	284	363	106			525	2716
	1959	Acres (000)	905	296	345	110			555	3078
Sugar produced	1950–59 av.	Tons (000)	1936	568	1162	1022	11	4699	1190	6109
	1959	Tons (000)	2340	616	1087	975	13	5031	1512	6625
Yield of sugar, harvested area	1950–59 av.	Tons/acre	2.39	2.00	3.20	9.64			2.27	2.25
Yield of sugar, total sugar cropland	1950–59 av.	Tons/acre	2.23	1.86	2.87	4.65			2.27	1.98
	1959	Tons/acre	2.45	1.93	2.82	4.37			2.72	1.71
Gross return on total sugar cropland, at wholesale[3]	1950–59 av.	Dollars/acre	252	210	324	525			–	158
	1959	Dollars/acre	281	222	324	502			–	102
Price paid independent growers for harvested crops[4]	1950–59 av.	Dollars/ton	11.46	7.14						
Program pay	1950–59 av.	Dollars/ton	2.35	1.15						
Total price and program pay	1950–59 av.	Dollars/ton	13.81	8.19						
	1959	Dollars/ton	13.70	8.25						
Sugar marketed, in continental U.S.A. (quota)	1959	Tons (000)	2241	578	958	977	12	4766	980	3215
Total production and imports	1959	Tons (000)						9240		

[1] Agricultural Statistics 1960. U. S. Dept. of Agriculture, U.S. Govt. Printing Office, Washington 25, D.C., 633 pp. 1961.
[2] Hawaii production curtailed by labor strikes; 1949 for 6 months, 1958 for 4 months.
[3] Average wholesale price for 96° cane sugar on cost, insurance, and freight basis: New York, 1950–59 average 5.64 cents per pound; 1959 at 5.74 cents per pound. Havana, Cuba, 1950–59 average 3.98 cents per pound; 1959 at 2.97 cents per pound. Returns do not include values for by-products. Retail price, granulated sugar, U.S., 1950–59, 10.4 cents per pound.
[4] Harvested cane or beets sold to processor. Program payments are supports paid under the U.S. Sugar Act of 1948, as amended.
[5] Because of adverse political relations between the U.S.A. and Cuba, the U.S.A. embargoed all commerce with Cuba in September 1960. Former Cuban sugar quotas to the U.S.A. will be reallocated to other sugar-producing areas. Imports from Cuba were 3,215,000 tons raw sugar value in 1959.

TABLE 2. Site data and rainfall at sugar beet test sites, H. C. & S. Co. plantation, Maui[1]

Site and Field No.		Kihei 817		Spreckelsville 609		Pulehu 405		Paia 204	
Elevation, feet		200		75		650		525	
Soil family		Molokai		Molokai		Lahaina		Kohala	
Soil series		Molokai silty clay, sloping		Molokai silty clay, sloping		Keahua silty clay, gently sloping		Hamakuapoko silty clay, sloping	
		Rainfall, Inches per Month							
Crop No.	*Year and Month*	*Period*	*Median 36 yr.*	*Period*	*Median 55 yr.*	*Period*	*Median 18 yr.*	*Period*	*Median 17 yr.*
	1959								
	Jan.	11.5	2.1	8.8	2.1	13.2	1.9	10.8	5.2
	Feb.	4.4	1.4	5.8	2.2	5.2	1.6	7.1	3.2
1	Mar.	T	1.3	1.3	1.8	0.1	1.8	3.3	5.6
1	April	0.3	0.2	3.2	1.4	1.6	0.4	6.4	3.6
1	May	0.5	0.1	1.6	0.7	0.6	0.1	3.4	2.4
1	June	0	0	0.1	0.3	0	0	1.1	1.6
1	July	0	T	0.5	0.5	0	0.1	2.2	2.9
1	Aug.	T	T	0.6	0.4	0.1	0.2	3.9	2.8
2	Sept.	0	0	0.2	0.4	0	0.1	1.3	1.2
2	Oct.	0	0.5	0.1	0.7	0	0.2	0.7	2.9
2	Nov.	1.1	0.4	2.8	1.4	1.9	1.0	4.8	3.4
2	Dec.	0.2	1.1	2.3	2.3	1.2	2.0	5.4	5.7
2	1960								
2	Jan.	0.4	2.1	1.3	2.1	0.5	1.9	2.7	5.2
2	Feb.	1.0	1.4	3.5	2.2	2.4	1.6	5.4	3.2
2	Mar.	0.2	1.3	2.1	1.8	1.1	1.8	4.2	5.6
	April	0	0.2	1.2	1.4	0.1	0.4	5.1	3.6
	Annual, median		12.3		21.3		13.8		44.8

[1] Detailed descriptions of soils are given by Cline *et al.* (5) and details on rainfall by Taliaferro (16). The Pineapple Research Institute-Hawaiian Sugar Planters' Association rainfall gauges are: Kihei 311, Spreckelsville 400, Pulehu 316, and Paia 416.

TABLE 3. Significance of various experimental factors in the production of two crops of sugar beets, H. C. & S. Co. plantation, Maui, 1959–60[1]

VARIANT	BEET YIELD,[2] CLEANED	BEET YIELD,[3] FULL STAND	POLARITY, PERCENT	PURITY, PERCENT	SUGAR YIELD,[4] TSAM
Site	**	**	**	**	**
Crop	NS	**	NS	NS	NS
Variety	**	**	**	**	**
Variety × Site	**	**	NS	NS	*
Variety × Crop	NS	NS	NS	NS	NS
Site × Crop	**	**	**	**	**
Variety × Site × Crop	NS	NS	NS	NS	NS

[1] Results based on three sites, Paia excluded. Statistical analysis of variance to establish whether variant has had significant effect in the performance of test sugar beet production. In table, NS = nonsignificant effect, * = significant effect at the 0.05 percent level of probability, ** = highly significant at the 0.01 percent level of probability. The experiment includes four test sites, four beet varieties, and two crops. The varieties were replicated eight times in randomized blocks. Plot size is 20 × 20 feet with beets 12 inches apart in rows 22 inches apart.

[2] Yield of beets cleaned and washed to remove soil.

[3] Beet yields corrected for dirt and adjusted to full stand.

[4] Sugar yield tons per acre per month, estimated from full stand of beets, polarity percent, purity percent, and age.

TABLE 4. Plant stand, percent of full stand of sugar beets at harvest, H. C. & S. Co. plantation, Maui, 1959–60

VARIETY	SITE OF FIELD TEST Kihei	Spreckelsville	Pulehu	Paia	VARIETY AVERAGE	RATIO
	First Crop, March to July 1959					
Growing days	143	143	143	152		
US 56/2	93.0	99.8	98.6	88.8	95.0	98
US 75	97.6	99.6	97.8	90.4	96.4	99
US 201	92.4	100.0	97.4	90.9	95.2	98
US 401	97.4	99.8	99.1	91.4	96.9	100
Site average	95.1	99.8	98.2	90.4	95.9	
Site ratio	95	100	98	96		
	Second Crop, August 1959 to March 1960					
Growing days	203	191	195	Failed[1]		
US 56/2	93.2	58.9	77.1	No Crop	57.3	100
US 75	93.8	61.6	72.1		56.9	99
US 201	93.5	49.4	71.3		53.6	94
US 401	89.8	55.2	69.8		53.7	94
Site average	92.5	56.3	72.6		55.4	
Site ratio	100	61	79	0		

[1] Paia site, second crop, damped-off in three successive seedings and failed to produce a crop.

TABLE 5. Yields of clean beets, tons per acre, H. C. & S. Co. plantation, Maui, 1959–60

VARIETY	SITE OF FIELD TEST: Kihei	Spreckelsville	Pulehu	Paia	VARIETY AVERAGE	RATIO
	First Crop, March to July 1959					
US 56/2	21.0	21.3	15.3	6.5	16.0	85
US 75	25.7	22.6	14.5	6.4	17.3	92
US 201	21.0	18.6	14.0	5.3	14.7	78
US 401	24.8	24.4	17.0	8.9	18.7	100
Site average	23.1	21.7	15.2	6.7	16.7	
LSD at 0.05 probability { Varieties	4.3	2.8	2.5	3.3	0.9	
LSD at 0.05 probability { Sites				0.5		
Site ratio	100	94	66	29		
	Second Crop, August 1959 to March 1960					
US 56/2	27.9	16.3	16.9	Crop failed	15.3	93
US 75	29.8	19.0	16.6		16.4	100
US 201	21.6	15.9	15.8		13.3	80
US 401	27.8	20.0	16.0		16.0	98
Site average	26.8	17.8	16.3		15.2	
Site ratio	100	66	61	0		
	Total for First and Second Crops in One Year[1]					
US 56/2	48.9	37.6	32.2		39.5	91
US 75	55.5	41.6	31.1		42.8	99
US 201	42.5	34.4	29.8		35.6	82
US 401	52.6	44.4	32.9		43.3	100
Site average	49.9	39.5	31.5		40.3	
LSD at 0.05 probability { Varieties			21.7		12.5	
LSD at 0.05 probability { Sites			14.3			
Site ratio	100	79	63			

[1] The Paia site is excluded.

TABLE 6. Yield of fresh, trimmed sugar beet tops, first crop, tons per acre, H. C. & S. Co. plantation, Maui, 1959–60

VARIETY	SITE Kihei	Spreckelsville	Pulehu	Paia	VARIETY AVERAGE	RATIO
US 56/2	11.9	9.5	7.7	5.2	8.6	80
US 75	12.9	10.1	7.1	4.5	8.7	80
US 201	13.7	13.0	7.8	5.9	10.1	94
US 401	14.4	13.4	8.9	6.4	10.8	100
Site average	13.2	11.5	7.9	5.5		
Site ratio	100	87	60	42		

TABLE 7. Average weight of clean and trimmed sugar beets, in pounds, H. C. & S. Co. plantation, Maui, 1959–60

VARIETY	SITE Kihei	Spreckelsville	Pulehu	Paia	VARIETY AVERAGE	RATIO
			First Crop			
US 56/2	2.10	1.96	1.43	0.67	1.54	88
US 75	2.42	2.08	1.36	0.64	1.63	93
US 201	2.09	1.70	1.32	0.54	1.41	80
US 401	2.34	2.24	1.57	0.89	1.76	100
Site average	2.24	2.00	1.42	0.68	1.59	
Site ratio	100	89	63	30		
			Second Crop			
US 56/2	2.74	2.49	2.01	No crop	2.41	87
US 75	2.92	2.84	2.11		2.62	95
US 201	2.12	2.90	2.04		2.35	85
US 401	2.86	3.33	2.10		2.76	100
Site average	2.66	2.89	2.07		2.54	
Site ratio	92	100	72			

TABLE 8. Average sugar beet juice polarization percent, H. C. & S. Co. plantation, Maui, 1959–60[1]

VARIETY		SITE				VARIETY AVERAGE	RATIO
		Kihei	Spreckelsville	Pulehu	Paia		
			First Crop				
US 56/2		13.39	13.09	14.61	13.91	13.75	98
US 75		12.56	13.03	14.37	14.19	13.54	97
US 201		13.34	13.68	14.66	14.17	13.96	100
US 401		12.45	12.87	14.69	13.58	13.40	96
Site average		12.94	13.16	14.58	13.96	13.66	
LSD at 0.05 levels	Varieties	1.62	1.21	1.08	1.28	1.22	
	Sites				0.61		
			Second Crop				
US 56/2		14.23	11.51	15.37	No crop	13.70	99
US 75		13.56	10.67	14.64		12.96	94
US 201		14.53	11.65	15.17		13.78	100
US 401		13.78	11.09	14.90		13.26	96
Site average		14.02	11.23	15.02		13.43	
			Average for First and Second Crops				
US 56/2		13.81	12.30	14.99		13.70	99
US 75		13.06	11.85	14.50		13.14	95
US 201		13.94	12.66	14.92		13.84	100
US 401		13.12	11.98	14.80		13.30	96
Site average		13.48	12.20	14.80		13.50	
LSD at 0.05 levels	Varieties			NS		0.46	
	Sites			0.40			

[1] The ripening of the sugar beets or the process of storing sucrose in the beets in the field was encouraged by limiting the supplies of irrigation water in the last third of the growing period. It is not to be inferred that maximum efficiency was obtained.

TABLE 9. Average sugar beet juice purity percent, H. C. & S. Co. plantation, Maui, 1959–60

VARIETY	SITE				VARIETY AVERAGE	RATIO
	Kihei	Spreckelsville	Pulehu	Paia		
First Crop						
US 56/2	80.37	82.24	85.15	85.29	83.26	99
US 75	80.99	82.71	85.33	85.34	83.59	99
US 201	81.44	83.66	85.34	85.81	84.06	100
US 401	80.32	83.26	85.41	85.51	83.62	100
Site average	80.78	82.96	85.31	85.49	83.64	
LSD at 0.05 level { Varieties	2.18	1.91	2.17	2.30	1.81	
LSD at 0.05 level { Sites				0.91		
Second Crop						
US 56/2	82.45	80.27	86.21	No crop	82.97	
US 75	81.81	79.21	85.84		82.28	
US 201	83.75	81.73	85.70		83.72	
US 401	82.49	79.27	87.42		83.06	
Site average	82.62	80.12	86.29		83.00	
Average for First and Second Crops						
US 56/2	81.41	81.26	85.68		82.78	
US 75	81.40	80.96	85.58		82.64	
US 201	82.60	82.70	85.52		83.60	
US 401	81.40	81.27	86.42		83.02	
Site average	81.70	81.55	85.80		83.01	

TABLE 10. Average yield of sugar beet sugar, tons of sugar per acre per month, H. C. & S. Co. plantation, Maui, 1959–60[1]

VARIETY	SITE				VARIETY AVERAGE	RATIO
	Kihei	Spreckelsville	Pulehu	Paia		
First Crop, March to July 1959						
Growing days	143	143	143	152		
US 56/2	0.474	0.480	0.379	0.151	0.376	88
US 75	.549	.511	.374	.152	.397	92
US 201	.478	.445	.368	.127	.355	83
US 401	.520	.548	.446	.203	.429	100
Site average	.505	.496	.397	.158	.389	
Second Crop, August 1959 to March 1960[2]						
Growing days	203	191	195	Failed		
US 56/2	0.483	0.236	0.369	0	0.363	100
US 75	.489	.252	.344	0	.362	100
US 201	.388	.227	.340	0	.318	88
US 401	.467	.276	.343	0	.362	100
Site average	.457	.248	.349	0	.351	
Average for First and Second Crops in One Year[2]						
US 56/2	0.478	0.358	0.374	0	0.403	93
US 75	.519	.382	.359		.420	97
US 201	.433	.336	.354		.374	86
US 401	.494	.412	.394		.433	100
Site average	.481	.372	.373		.408	
Site ratio	100	77	77			

[1] Yields obviously were reduced because of loss of stand or population in accordance with census taken at harvest.
[2] The yields at Paia are not included.

TABLE 11. Potential yield of sugar, tons of sugar per acre per month, for sugar beets adjusted to full stand, H. C. & S. Co. plantation, Maui, 1959–60[1]

VARIETY	SITE: Kihei	Spreckelsville	Pulehu	Paia	VARIETY AVERAGE	RATIO
	First Crop, March to July 1959					
US 56/2	0.515	0.481	0.405	0.170	0.393	90
US 47	.562	.513	.382	.167	.406	92
US 201	.518	.445	.377	.140	.370	84
US 401	.534	.549	.450	.222	.439	100
Site average	.532	.497	.404	.175	.402	
LSD at 0.05 level { Varieties	.079	.087	.051	.074		
LSD at 0.05 level { Sites						
	Second Crop, August 1959 to March 1960					
US 56/2	0.518	0.395	0.446	No crop	0.453	92
US 75	.522	.412	.444		.459	93
US 201	.415	.475	.445		.445	90
US 401	.524	.504	.458		.495	100
Site average	.495	.446	.448		.463	
	Average for First and Second Crops in One Year[2]					
US 56/2	0.516	0.438	0.426		0.460	91
US 75	.542	.462	.413		.472	94
US 201	.466	.360	.411		.412	82
US 401	.529	.526	.454		.503	100
Site average	.513	.446	.426		.462	

[1] Estimates of potential yields of sugar assume constant rates of productivity varying directly with the plant census at harvest time at each site.
[2] The yields at Paia are not included.

TABLE 12. Comparison of estimated sugar production from sugar beet test fields with actual sugar yields of the same fields with sugar cane, H. C. & S. Co. plantation, Maui, 1949–60[1]

FACTOR	KIHEI	SPRECKELSVILLE	PULEHU	PAIA[2]	AVERAGE	RATIO, ALL CROPS	REFERENCE
			Estimated Total Sugar Beet Production				
Period, years	1959–60	1959–60	1959–60	1959–60			Table 8
No. crops	2	2	2	2			No deduction
Age, months	5.77	5.57	5.41	5.07	5.46		for handling
TSAM[3]	0.481	0.372	0.373	0.079	0.326		losses
Yield percent of cane	103	78	70	16		67	
			Potential Sugar Beet Production, Yield Adjusted to Full Stand				
No. crops	2	2	2	1			Table 9
TSAM	0.513	0.446	0.426	0.175	0.390		No deduction
Yield percent of cane	110	94	80	36		80	for losses
			Actual Sugar Cane Production				
Period, years	1951–57	1951–57	1949–57	1950–56			Plantation
No. harvests	4	4	5	4			data, net
Age, months	24.18	23.73	24.15	23.94	24.00		yield before
TSAM	0.467	0.476	0.531	0.484	0.490	100	field and mill losses

[1] Comparison of sugar productivity is between actual turnout of sugar from plantation cane fields ranging from 130 to 289 acres in size as against estimated total sugar from field-grown sugar beets on 2-acre test areas from the same fields.

[2] At the Paia site the second beet crop failed because of damping-off of seedlings. Data shown are derived from the first crop.

[3] Sugar production in tons of sugar per acre per month.

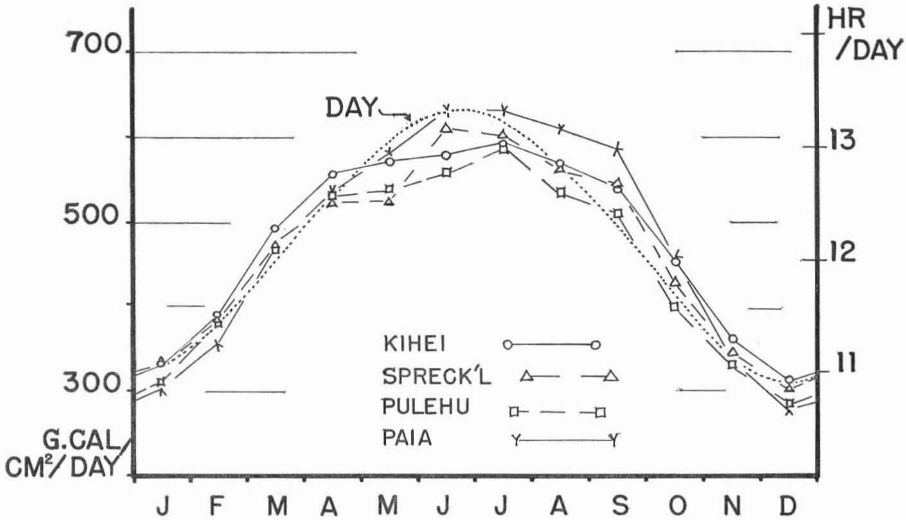

FIGURE 5. Seasonal distribution of solar energy at selected sites at H. C. & S. Co. plantation, Maui. Mean monthly gram calories per square centimeter calculated to a daily value, 1954–1959. Daily solar energy distribution closely follows the shift in daylength hours. The site curves are similar and show no differentiation related to differences in sugar beet yield.

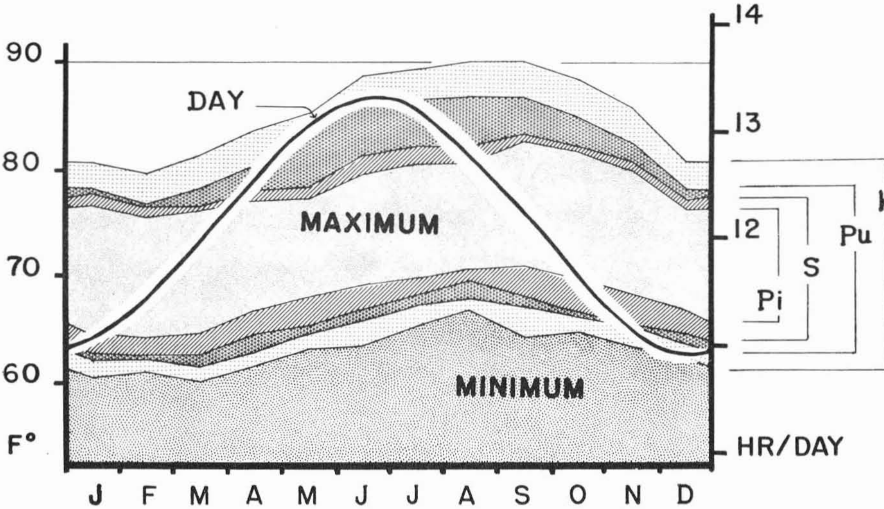

FIGURE 6. Seasonal distribution of daily maximum and minimum temperatures at selected sites at H. C. & S. Co. plantation, Maui. Monthly means of daily temperatures, 6-year average, 1954–1959. Some relationship appears to exist between temperature extremes and beet yield. Kihei with highest maxima and lowest minima produced highest beet and sugar yields. Paia with the least temperature variation had the poorest beet yields. The temperature extremes are fairly stable and appear to bear little relationship to length of day.

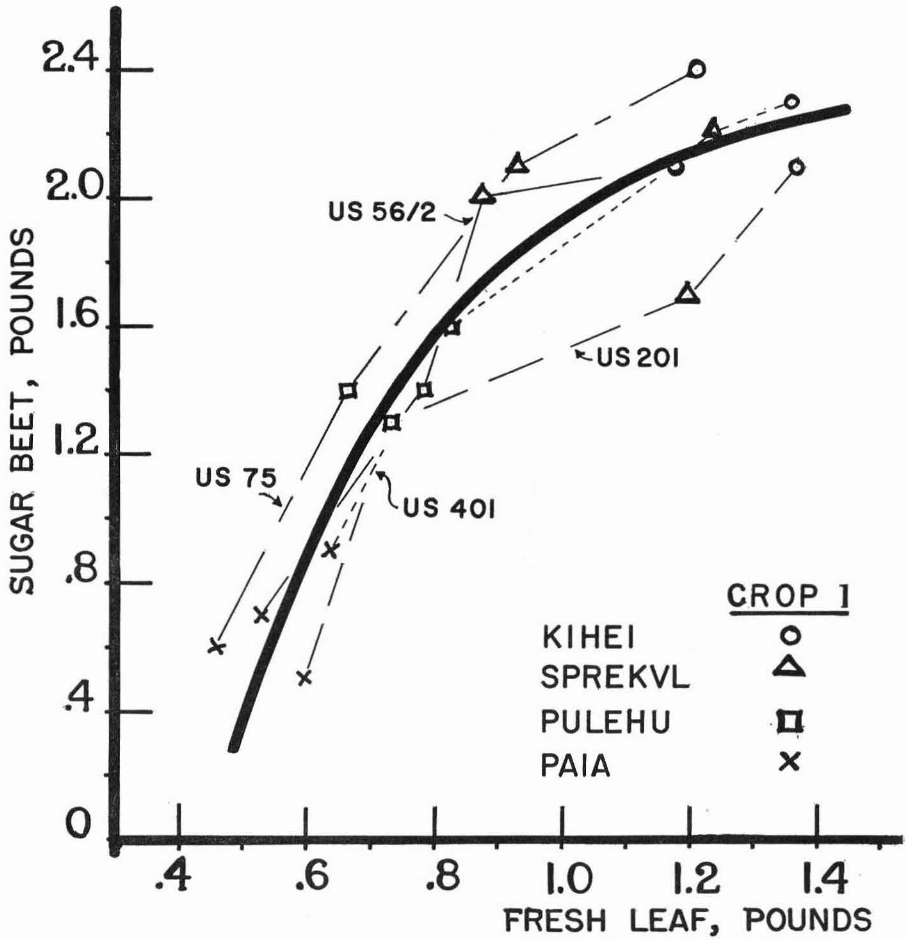

FIGURE 7. Relationship of leaf weight to unit weight of clean sugar beets, first crop, H. C. & S. Co. plantation, Maui, 1959. Beets were spaced at 12 inches in rows 22 inches apart. The positive relationship of leaf weight to beet weight is curvilinear. Increasing leaf weight beyond about 1.5 pounds leaf per beet would appear to produce little increase in beet weight and yield. Closer spacing of the sugar beets might result in higher acre yields.

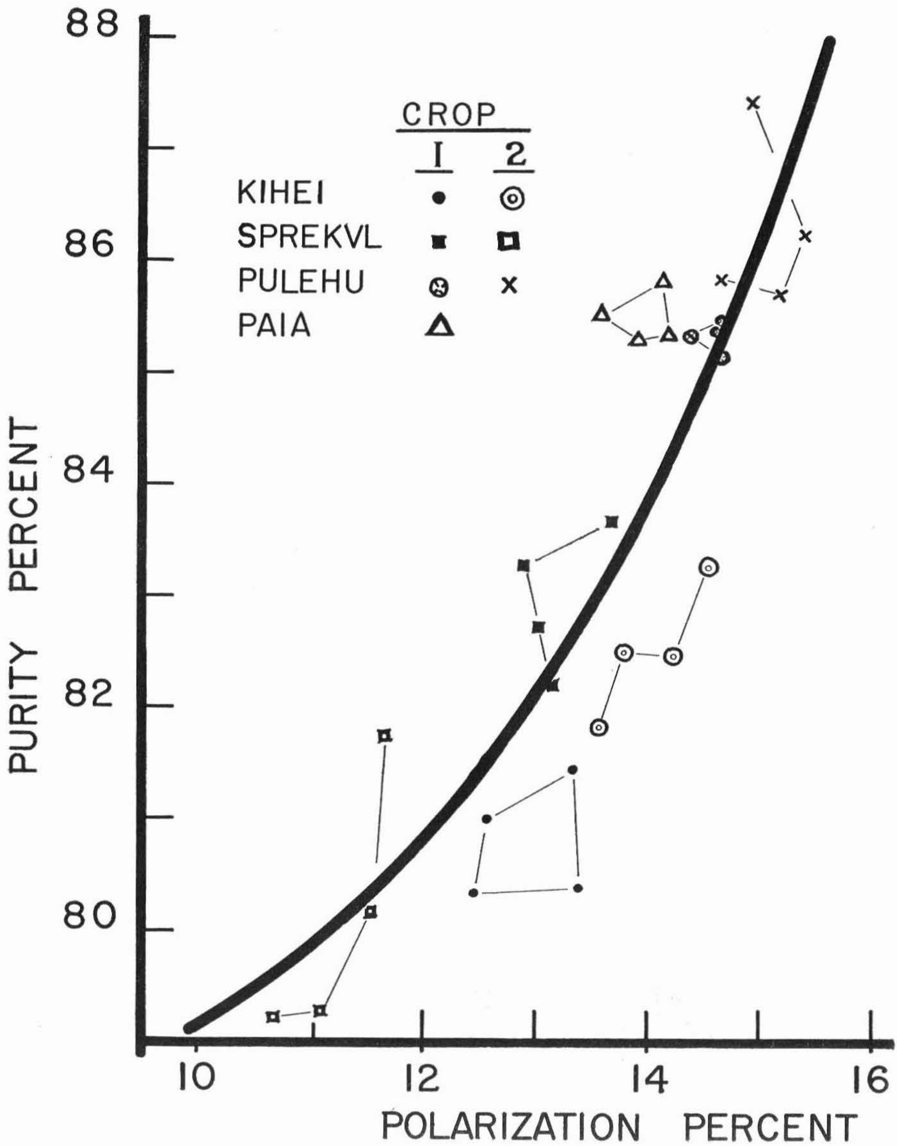

FIGURE 8. Relationship of total sugars to sucrose concentration of sugar beet juices shows the high beet-yielding sites of Kihei and Spreckelsville to have the poorest juices. The relationship between the pol percent and the purity percent is quite evident. The sugar content of the experimental beets is at the low end of the usual range of 12 to 22 percent sugar content.

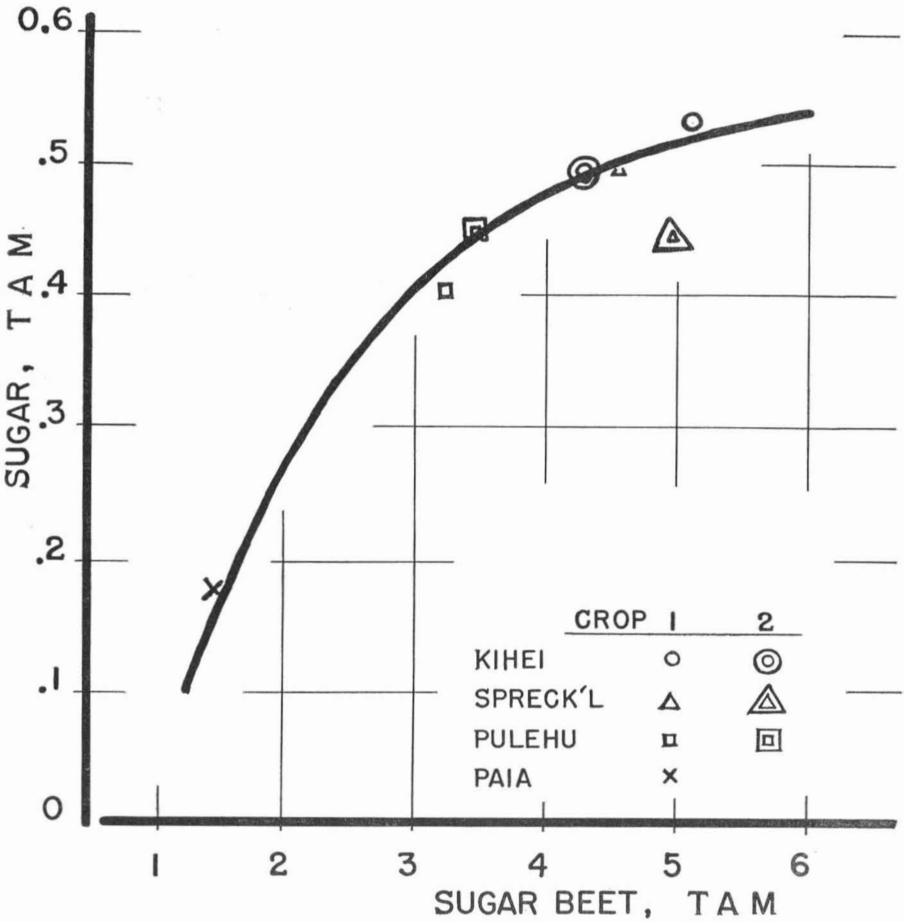

FIGURE 9. The relationship of sugar yields per acre per month to yields of beets is shown for four test sites and two crops, H. C. & S. Co. plantation, Maui, 1959–60. The relationship between beet yield and sugar turnout is definitely curvilinear in these tests. The flat shape of the curve at the higher yield levels suggests top sugar yields from sugar beets lie at about 0.55 ton per acre per month, under conditions similar to those of these experiments.

UNIVERSITY OF HAWAII
COLLEGE OF TROPICAL AGRICULTURE
HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

THOMAS H. HAMILTON
President of the University

MORTON M. ROSENBERG
Dean of the College and
Director of the Experiment Station

G. DONALD SHERMAN
Associate Director of the Experiment Station